

## UNITED STATES AIR FORCE RESEARCH LABORATORY

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### DIODE PUMPED FREQUENCY DOUBLED ND: YAG LASER FOR THE TREATMENT OF GLAUCOMA AND RETINAL DISEASE

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14. ABSTRACT The program achievements were as follows: <ul style="list-style-type: none"> <li>- A diode pumped frequency doubled Nd:YAG laser system with adapters for commercial slit lamps was developed with the desired portability. The laser unit had a footprint of about 10" x 14" and weighed less than 20 kg. The frequency doubled Nd:YAG laser operating at 532 nm had substantially the same efficacy as the large Argon ion laser operating at 514 nm. The Nd:YAG laser achieved equivalent treatments as the Argon ion laser, at slightly lower power levels</li> <li>- Successful clinical trials were performed for the treatment of glaucoma and for one type of retinal disease. However, the number of patients treated was quite small. Full results are given in the report.</li> <li>- The lasers used in the clinical trials were similar to the commercial units co-developed by our associates in Europe. The original technology transferred in Phase I, based on work done at the Air Force Research Laboratory's Phillips Research Site in Albuquerque NM (formerly Phillips Laboratory), was not directly used in the clinical units because significant thermal problems were found when the Phase I laser was enclosed to develop a commercial-style clinical laser unit.</li> </ul>					
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## TABLE OF CONTENTS

<b>Executive Summary .....</b>	<b>1</b>
<b>Overall Program Structure</b>	
<b>Phase I .....</b>	<b>2</b>
<b>Phase II.....</b>	<b>3</b>
<b>Clinical Results</b>	
<b>Glaucoma Treatment And Results .....</b>	<b>5</b>
<b>Retinal Disease Treatment And Results .....</b>	<b>5</b>
<b>Chronological Summary of Laser Development.....</b>	<b>7</b>
<b>Conclusions .....</b>	<b>9</b>
<b>Appendix A, Glaucoma Treatment Results, Data And     Statistics.....</b>	<b>A-1</b>
<b>Appendix B, Arvo 2000 Abstract And Slides .....</b>	<b>B-1</b>

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## EXECUTIVE SUMMARY

Results are presented for a Small Business Technology Transfer (STTR) Phase II program to test the efficacy of the cw diode pumped frequency doubled Nd:YAG laser in the clinical treatment of glaucoma and retinal abnormalities. The Phase I laser was based on the design developed by researchers at the Air Force Research Laboratory Phillips Research Site (formerly Phillips Laboratory). Additionally the output power from the laser developed in Phase I was to be raised first to about 3 watts and then higher towards 10-15 watts.

Successful clinical trials were performed for the treatment of glaucoma and for one type of retinal disease. However, the number of patients treated was quite small. Full results are given in the report.

The lasers used in the clinical trials were similar to the commercial units co-developed by our associates in Europe. The original technology, based on work done at the Air Force's Phillips Laboratory in Albuquerque, NM, was not directly used in the clinical units. As the Phase I laser was enclosed to develop a prototype clinical laser unit, significant thermal problems were found. After spending about a year trying to remedy this within the original laser technology, it was decided to purchase a green laser engine as a subunit from an outside supplier. Significant time was also spent working on the interface between the lasers and selected slit lamps. The clinical trials concluded using Haag-Streit slit lamps for which special adapters were fabricated from components purchased from a Swiss company.

In summary, the program achievements were the following. A diode pumped frequency doubled Nd:YAG laser system with adapters for commercial slit lamps was developed with the desired portability. The laser unit had a footprint of about 10" x 14" and weighed less than 20 kg. The frequency doubled ND:YAG laser operating at 532 nm had substantially the same efficacy as a large argon ion laser operating at 514 nm. The new laser achieved equivalent treatments as the argon ion laser at slightly lower power levels.

## **OVERALL PROGRAM STRUCTURE**

### **Phase I**

Phase I focused on demonstrating the safety and efficiency of a continuous wave (cw) diode pumped frequency doubled Nd:YAG laser for the treatment of glaucoma. In vitro and in vivo experiments were conducted to establish safety and to identify the procedures best suited for this laser. The Nd:YAG laser was fabricated according to the design developed at the Air Force Phillips Laboratory. A significant result of the Phase I work was verification of the assumption that the cw diode pumped frequency doubled Nd:YAG laser effected a tissue response nearly identical to that observed with an argon ion laser at identical power spot size, and pulse duration.

### **Development Team for Phase I**

The team was comprised of the following:

- Dr. Rafael A. Sierra, Fiber Optic Fabrications, Inc. (Prime Contractor)
- Dr. Peter A. Netland, Harvard University/Mass Eye & Ear Infirmary  
(University/Hospital,)
- Dr. Peter S. Durkin, Phillips Lab, AFRL (AF Program Monitor)

### **Phase I Conclusions**

The laser design described by Durkin and Post can be adapted to provide laser output suitable for therapeutic applications in ophthalmology. A prototype laser built at FFI was successfully used both in vitro and in vivo to perform surgical procedures commonly used in the management of glaucoma. The potential low cost and portable nature of the laser ensures the success of this laser commercially. In addition, access to laser treatment can be expanded to include patients that have limited mobility or that are located in remote regions where the equivalent argon ion lasers may not be readily available.

All data demonstrated that tissue response to the frequency doubled Nd:YAG laser radiation was largely equivalent to the response of the tissue to the argon ion laser

radiation at similar output power, pulse duration, and spot size. The Phase I work concentrated on procedures commonly used in the management of glaucoma. The great similarity between tissue responses to the frequency doubled Nd:YAG laser and to the argon ion laser supported expanding the indications for this laser to encompass all ophthalmic conditions commonly treated with the argon ion laser. Expansion of the work to include all ophthalmic indications currently addressed with the argon ion laser was recommended for Phase II.

While animal models can be used to establish safety of a laser treatment, efficacy must be demonstrated in human clinical studies. Based on the results of the Phase I study, clinical trials of procedures related to the management of glaucoma were indicated. Also, the retinal data at the conclusion of phase 1 were only preliminary, and further clinical studies of retinal treatment needed additional in vitro and in vivo studies. These studies were proposed as part of the Phase II effort.

## **Phase II**

Phase II focused on converting the breadboard laser to a prototype clinical laser with adequate power to perform the various clinical applications and to carry out the clinical trials in treatment of glaucoma retinal abnormalities. Additional animal studies were needed to prepare the necessary forms for the approvals authorizing human studies before clinical testing could begin. Power was increased to about 3 watts cw at the laser head. Losses due to the preferred small diameter output fiber and to the adapter and optics of the slit lamp required the laser to have more than the original 1.5 watts. Due to the thermal problems which beset the Phase I technology as the laser was incorporated into quasi-commercial units, the major developments in Phase II were to increase the power and stability of the green output, and to prepare units which the doctors could use with the slit lamps available to them in their practices.

## **Development Team for Phase II**

Team comprised:

- Dr. Bolesh J. Skutnik, Fiber Optic Fabrications, Inc. (Prime Contractor)



- Mr. Michael Quade, Fiber Optic Fabrications, Inc.
- Dr. William G. Stinson, Harvard Medical School/Mass Eye & Ear Infirmary  
(University/Hospital, Retinal Abnormalities)
- Dr. Joel S. Schuman, Tufts Medical School/New England Eye Center  
(University/Medical Center, Glaucoma)
- Maj. R. Kang, Maj. K. Harrington, Lt. Col. N.G. Luthman, Air Force  
Research Laboratory, AFRL/HEDO (AF Program Monitors)

## **CLINICAL RESULTS**

### **GLAUCOMA TREATMENT AND RESULTS**

Joel S. Schuman, MD, Professor of Ophthalmology, Chief, Glaucoma Service, New England Eye Center, Tufts University School of Medicine, was the principle investigator for this study. A total of six participants were enrolled. Treatments took place between the months of January and December 2000. Two treatments took place in January, three in March, and one in December. Each participant completed a six week and six month postoperative visit. Enrollment was sparse, and was discontinued due to lack of interest on the part of subjects, as well as the introduction of new technology (nanosecond pulsed fd Nd:YAG laser selective laser trabeculoplasty).

Mean age was 66 years. The average  $\pm$  standard deviation preoperative intraocular pressure was  $17.3 \pm 1.2$  mmHg for ALT treated eyes and  $23.7 \pm 3.8$  mmHg for fd Nd:YAG laser treated eyes. The mean IOPs at six weeks were  $15.3 \pm 1.5$  mmHg for ALT treated eyes and  $20.3 \pm 5.5$  mmHg for fd Nd:YAG laser treated eyes, and at six months were  $19.7 \pm 3.2$  mmHg for ALT treated eyes and  $20.3 \pm 7.5$  mmHg for fd Nd:YAG laser treated eyes. There was no statistically significant difference between groups in terms of IOP lowering efficacy; however, the sample sizes were extremely small.

A table summarizing the demographic and IOP response data and the statistical analyses are in appendix A.

### **RETINAL DISEASE TREATMENT AND RESULTS**

The purpose of this study was to determine the efficacy of a frequency doubled Nd:YAG laser to treat various retinal diseases which are traditionally treated with a more cumbersome, argon laser. The retinal disease study was conducted by William G. Stinson, M.D. Animal studies indicated results were clinically, angiographically, and histologically similar to the Argon green laser with slightly lower power requirements.

(appendix B). Initially, a study definition and data collection techniques were created followed by recruiting clinicians. Once the procedures were completed, the study began and continued for approximately one year. At this time the study data was reviewed and determined to be insufficient. Due to enrollment limitations stated below, it was decided to terminate the study.

The study was formally designed as an A to B comparison between the two separate lasers, Argon and fd Nd:YAG, to prove functional equivalence. To accomplish this, data collection techniques were devised for the three arms of the study, and they were as follows:

- Clinically significant macular edema in diabetes [CSME]
- Age related macular degeneration [ARMD]
- Retinal treatment to produce chorio/retinal adhesion in treatment of retinal tear (Retinopexy)

In the CSME arm, the measurement variable was visual acuity at 3, 6, and 12 months. In the ARMD arm, the measurement variable was angiogram data indicating evidence of closure or recurrence/persistence of neovascularization at 2, 6, 12, and 24 weeks. In the Retinopexy arm, the measurement variable was an office note indicating chorio/retinal scar/break sealed at 1 day, 6 days, and 24 weeks. To accomplish this, 5 retinal surgeons from the metro Boston area were selected.

The study collected data for approximately one year. Two patients were enrolled in the CSME arm and were randomized to the Argon laser. They both had the procedure performed on their right eye. Their results were as follows:

Patient	Eye	Pre study	3 Months	6 Months	12 Months
CSME 1	OS	20/64 +2	20/20 -1	20/25 -2	No data
CSME 1	OD	20/20	20/40 +1	20/50 +1	No data
CSME 2	OS	20/40 +1	20/50 -2	20/50 +1	No data
CSME 2	OD	20/80 +1	20/64 +1	20/50 +1	No data

Neither of the other two arms, ARMD nor Retinopexy produced reportable data.

This study encountered severe difficulties with patient recruitment, which hindered the results to the point of terminating the study. The Nd:YAG laser development lagged far behind the clinical relevance. Patients were not willing to try a new laser technology to confirm now current technology. Additionally, patients were not willing to travel into Boston, and when a suburban location was offered, said patients had little or no interest in participating. Surgeons also had little motivation to recruit patients to confirm current technology. Numerous attempts to initiate a "one day" type clinic failed because of a lack of interest from both facilities and patients.

Although the Nd:YAG laser technology is a viable option, and now in de facto use, this study was unable to collect sufficient data to confirm this based on the limitations stated above.

### **CHRONOLOGICAL SUMMARY OF LASER DEVELOPMENT**

The Phase II program began with the addition of a doctor for retinal disease studies, who became the lead investigator for the preclinical and clinical studies when the co-investigator and subordinate doctors from Phase I left the Massachusetts Eye and Ear Institute (MEEI) and New England. Dr. William Stinson became co-investigator in July 1997, and, with the approval of Major Kang, Dr. Joel Schmann joined the group to perform the glaucoma treatments. During April, Dr Skutnik took over as principal investigator from Dr. Rafael Sierra who left the company.

During the first year, additional animal studies were done with a breadboard laser and, after the approval of the IRB at MEEI, with first quasi-commercial units using the Durkin technology from Kirtland AFB, which was employed in Phase I. The closed units in December began to demonstrate the thermal effects which came to plague the original design. During the first year work also began on improving the fiber coupling to the pump diode array source with preliminary drawing of non-circular cross-section optical fibers.

During the second year, major work included software updates to stabilize the output, purchase of slit lamps adapted for laser application, and development of a coupling system to get the laser beam into and through the slit lamp more efficiently than using the teaching Coherent slit lamp available at MEEI laboratories. Several approaches were tried to improve stability of the green laser power output. These efforts led to dropping the original design and opting for a commercially available green laser engine as the starting point for the medical laser. This also required the redesign and enlargement of the case for the laser system. By mid year the benefit for output stability of operating at maximum desired power with an attenuator to adjust to lower energy requirements became clear. An attenuator was incorporated and adjusted to be reliable, reproducible and efficient. Due to lingering problems, one of the upgraded lasers was not available until after year's end and larger than desired delivery fibers were being used. A separate non-green aiming beam was introduced during the redesigning process with the new laser engines. The original red aiming beams were upgraded with brighter aiming beams by the end of the year. With the newer green laser engines output at the laser was raised from the 1.5 to 2 W maximum, and finally to about 3 W maximum. Beyond this the ophthalmologists could see no reason to go to higher output levels and thus further development was stopped.

During the third year, all of the improvements from iterative testing by the doctors yielded two clinical units with proper stability, improved incremental adjustments for low energy applications, new attenuators, the provision of safety filters and the adaptation of Haag-Streit slit lamps for use with either the old illumination plug set ups or the new ones. A paper was presented at ARVO on animal results obtained during the second and third year of the program. The final animal tests were run and histology and pathology tests analyzed by the end of the year. The hospital Science Review Board essentially gave approval to the clinical testing. Also the Health Safety Board at MEEI also approved the clinical trial protocols. The various minor problems that arose were handled as quickly as possible with reasonable turnarounds for repairs or corrections. Note that our co-located commercialization affiliate purchased the green laser engines for the clinical trial

devices and incorporated them into their cases at their cost under their independent development of the Ceralas<sup>®</sup> G, Diode Pumped Frequency-Doubled Nd:YAG green laser. They also obtained a 510(k) for that product, of which the doctors did not make full use in their pursuit of approvals at MEEI. This plus their late decision to use only Haag-Streit slit lamps, for which adaptors needed to be negotiated from the Swiss home office stretched out the start of clinical trials into 2000, year four.

## CONCLUSIONS

In their initial design, the frequency doubled Nd:YAG laser displayed significant thermal stability problems within the size restrictions required for portability, giving rise to varying outputs of the green treatment beam. This was determined in physical testing and in preclinical animal testing during Phase II work. The remedy was to enlarge the laser unit footprint from about 8" x 10" and weight from about 12 kg to the size and weight given below for the final units. The final system was designed and used with the most popular slit lamp system, namely, the Haag-Streit one. It also was adapted and tested with other slit lamps including a Zeiss slit lamp.

Delays in the availability of clinical laser prototypes, caused by finding solutions to the beam output stability due to the thermal stability problems within the laser unit and to the adaptation of the laser output for both old and new Haag-Streit slit lamps, probably created some of the problems experienced in the final recruitment of patients for the clinical trials. The novelty of the diode pumped frequency doubled Nd:YAG units was somewhat compromised by the introduction of a similar operating unit by another commercial firm.

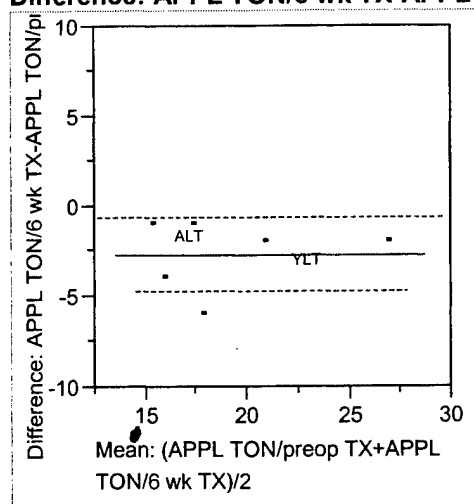
In summary, two clinical prototype laser systems were used successfully to treat glaucoma and 'clinically significant' macular edema in patients, the latter in diabetic patients. The laser systems, which were diode pumped frequency doubled Nd:YAG laser systems with adapters for commercial slit lamps, were developed with the desired portability. The laser unit had a footprint of about 10" x 14" and weighed less than 20 kg. The frequency doubled Nd:YAG laser operating at 532 nm had substantially the same efficacy as the large Argon ion lasers operating at 514 nm. The new laser achieved equivalent treatments as the Argon ion laser at slightly lower power levels.

## APPENDIX A, GLAUCOMA TREATMENT RESULTS, DATA AND STATISTICS

PARTICIPANT NUMBER	GENDER	DOB	TREATMENT DATE	TREATMENT	TREATED EYE	APPL TON preop TX	APPL TON preop CON	APPL TON 6 wk TX	APPL TON 6 wk CON	APPL TON 6 mos TX	APPL TON 6 mos CON
IOP-01	F	2/8/30	3/9/00	ALT	OD	16	16	15	16	16	16
IOP-02	F	5/5/32	3/9/00	ALT	OS	18	18	17	19	22	24
IOP-03	M	1/31/42	3/29/00	YLT	OS	21	15	15	18	13	33
IOP-04	F	10/5/40	1/27/00	YLT	OS	22	18	20	18	20	18
IOP-05	M	4/24/31	12/19/00	YLT	OD	28	22	26	23	28	24
IOP-06	M	6/8/32	1/31/00	ALT	OS	18	18	14	22	21	10
<b>AVERAGE</b>		<b>11/3/34</b>			<b>OVERALL</b>	<b>20.500</b>	<b>17.833</b>	<b>17.833</b>	<b>19.333</b>	<b>20.000</b>	<b>20.833</b>
<b>STD DEV</b>					<b>SD</b>	<b>4.278</b>	<b>2.401</b>	<b>4.535</b>	<b>2.658</b>	<b>5.177</b>	<b>7.960</b>
					<b>ALT</b>	<b>17.333</b>	<b>17.333</b>	<b>15.333</b>	<b>19.000</b>	<b>19.667</b>	<b>16.667</b>
					<b>SD</b>	<b>1.155</b>	<b>1.155</b>	<b>1.528</b>	<b>3.000</b>	<b>3.215</b>	<b>7.024</b>
					<b>YLT</b>	<b>23.667</b>	<b>18.333</b>	<b>20.333</b>	<b>19.667</b>	<b>20.333</b>	<b>25.000</b>
					<b>SD</b>	<b>3.786</b>	<b>3.512</b>	<b>5.508</b>	<b>2.887</b>	<b>7.506</b>	<b>7.550</b>

# Matched Pairs

Difference: APPL TON/6 wk TX-APPL TON/preop TX



APPL TON/6 wk TX	17.8333	t-Ratio	-3.32182
APPL TON/preop TX	20.5	DF	5
Mean Difference	-2.6667	Prob >  t	0.0210
Std Error	0.80277	Prob > t	0.9895
Upper95%	-0.6031	Prob < t	0.0105
Lower95%	-4.7302		
N	6		
Correlation	0.90205		

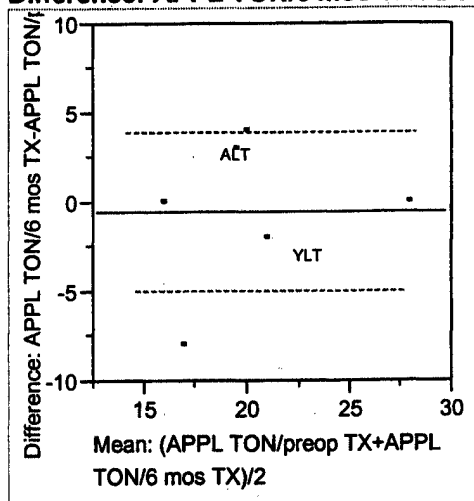
## Across Groups

TREATMENT	Count	Mean Difference	Mean Mean
ALT	3	-2	16.333
YLT	3	-3.333	22

Test Across Groups	F Ratio	Prob>F	
Mean Difference	0.6400	0.4685 Within Pairs	Y Axis
Mean Mean	4.3623	0.1050 Among Pairs	X Axis



# **Difference: APPL TON/6 mos TX-APPL TON/preop TX**



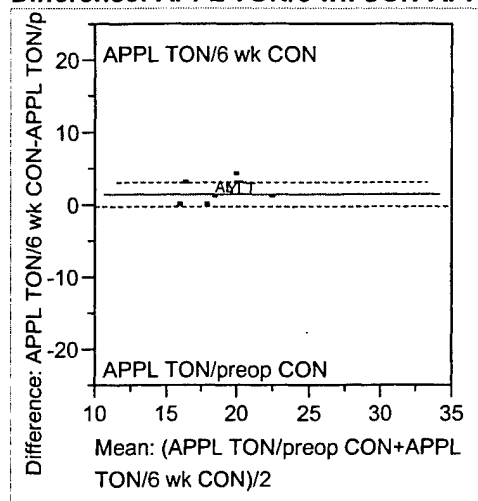
APPL TON/6 mos TX	20	t-Ratio	-0.2863
APPL TON/preop TX	20.5	DF	5
Mean Difference	-0.5	Prob >  t	0.7861
Std Error	1.74642	Prob > t	0.6069
Upper95%	3.98926	Prob < t	0.3931
Lower95%	-4.9893		
N	6		
Correlation	0.60508		

## **Across Groups**

TREATMENT	Count	Mean Difference	Mean Mean
ALT	3	2.3333	18.5
YLT	3	-3.333	22

Test Across Groups	F Ratio	Prob>F		
Mean Difference	4.4462	0.1027	Within Pairs	Y Axis
Mean Mean	1.0280	0.3680	Among Pairs	X Axis

# Difference: APPL TON/6 wk CON-APPL TON/preop CON



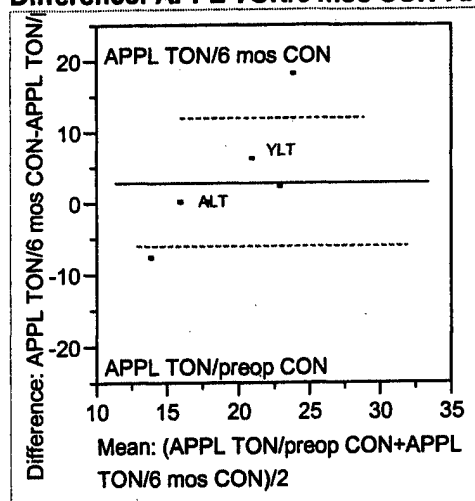
APPL TON/6 wk CON	19.3333	t-Ratio	2.236068
APPL TON/preop CON	17.8333	DF	5
Mean Difference	1.5	Prob >  t	0.0756
Std Error	0.67082	Prob > t	0.0378
Upper95%	3.22437	Prob < t	0.9622
Lower95%	-0.2244		
N	6		
Correlation	0.79369		

## Across Groups

TREATMENT	Count	Mean Difference	Mean Mean
ALT	3	1.6667	18.167
YLT	3	1.3333	19

Test Across Groups	F Ratio	Prob>F	
Mean Difference	0.0500	0.8340 Within Pairs	Y Axis
Mean Mean	0.1506	0.7177 Among Pairs	X Axis

# **Difference: APPL TON/6 mos CON-APPL TON/preop CON**



APPL TON/6 mos CON	20.8333	t-Ratio	0.849662
APPL TON/preop CON	17.8333	DF	5
Mean Difference	3	Prob >  t	0.4343
Std Error	3.53082	Prob > t	0.2172
Upper95%	12.0761	Prob < t	0.7828
Lower95%	-6.0761		
N	6		
Correlation	-0.1482		

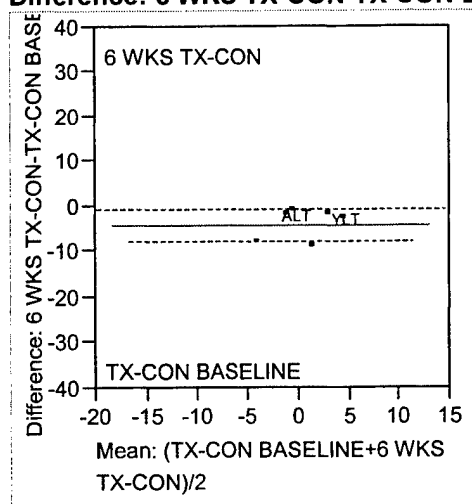
## **Across Groups**

TREATMENT	Count	Mean Difference	Mean Mean
ALT	3	-0.667	17
YLT	3	6.667	21.667

Test Across Groups	F Ratio	Prob>F	
Mean Difference	1.1000	0.3535 Within Pairs	Y Axis
Mean Mean	2.8000	0.1696 Among Pairs	X Axis

# Matched Pairs

Difference: 6 WKS TX-CON-TX-CON BASELINE



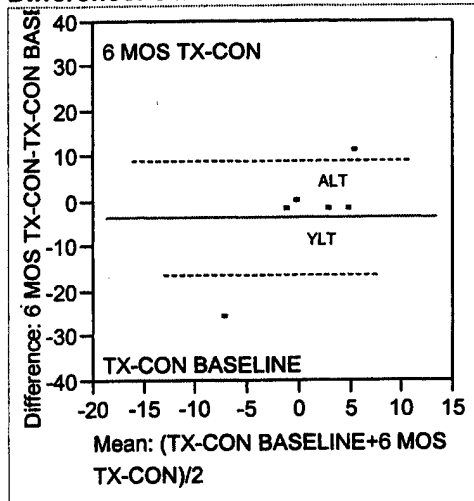
6 WKS TX-CON	-1.5	t-Ratio	-2.97535
TX-CON BASELINE	2.66667	DF	5
Mean Difference	-4.1667	Prob >  t	0.0310
Std Error	1.4004	Prob > t	0.9845
Upper95%	-0.5669	Prob < t	0.0155
Lower95%	-7.7664		
N	6		
Correlation	0.53987		

## Across Groups

TREATMENT	Count	Mean Difference	Mean Mean
ALT	3	-3.667	-1.833
YLT	3	-4.667	3

Test Across Groups	F Ratio	Prob>F	
Mean Difference	0.1047	0.7625 Within Pairs	Y Axis
Mean Mean	12.0143	0.0257 Among Pairs	X Axis

# **Difference: 6 MOS TX-CON-TX-CON BASELINE**



6 MOS TX-CON	-0.8333	t-Ratio	-0.70687
TX-CON BASELINE	2.66667	DF	5
Mean Difference	-3.5	Prob >  t	0.5112
Std Error	4.95143	Prob > t	0.7444
Upper95%	9.22787	Prob < t	0.2556
Lower95%	-16.228		
N	6		
Correlation	-0.4769		

## **Across Groups**

TREATMENT	Count	Mean Difference	Mean Mean
ALT	3	3	1.5
YLT	3	-10	0.3333

Test Across Groups	F Ratio	Prob>F		
Mean Difference	2.1037	0.2206	Within Pairs	Y Axis
Mean Mean	0.0762	0.7962	Among Pairs	X Axis

## APPENDIX B. ARVO 2000 Abstract and Slides

DIODE PUMPED FREQUENCY DOUBLED ND: YAG LASER  
VS ARGON GREEN IN EXPERIMENTAL RETINAL LESIONS  
(( W.G. Stinson,<sup>1</sup> D. Husain,<sup>1</sup> M. Saleeb,<sup>1</sup> B Skutnik<sup>2</sup>))  
Massachusetts Eye and Ear Infirmary, Harvard Medical School,  
Boston, MA<sup>1</sup>, Fiberoptic Fabrications, Inc. East Longmeadow,  
MA.<sup>2</sup>

**Purpose:** To study and compare the clinical, angiographic, and histologic effects of a Diode pumped frequency doubled Nd: YAG (FDYAG) laser ( $\lambda=532$  nm) with an Argon green laser ( $\lambda=514$  nm) in a rabbit model.

**Methods:** Standardized laser burns of 0.1 second duration and 100  $\mu$ m spot size were produced in 5 Dutch Belted rabbit eyes with both lasers varying power settings between 50 and 400 milliwatts to establish thresholds for the clinical endpoints of mild retinal blanching and breaking Bruch's Membrane. Comparable spots were placed with both lasers in a single fundus to control for variations in pigmentation. Treatment spots were compared acutely, and out to four weeks with fundus photography, angiography, and histology.

**Results:** The FDYAG laser produced comparable lesions to the argon green laser with slightly lower thresholds for creating both a visible retinal lesion (FDYAG = 57.5 mW vs. Argon green = 60 mW) and for breaking Bruch's Membrane (FDYAG = 259 mW vs. Argon green = 280 Mw).

**Conclusions:** The FDYAG laser produces fundus lesions which are clinically, angiographically, and histologically similar to the Argon green laser with slightly lower power requirements.

Support: SBTTR Grant AF41624-97-C-9000

## Background

A solid state, diode pumped, continuous wave, frequency doubled Nd:YAG (FDYAG) laser offers increased portability with simpler power and cooling requirements than an argon laser.

Early reports in the literature used pulsed FDYAGs.<sup>1,2</sup>

Scant data exists on the comparative effects of a cw FDYAG laser.<sup>3,4</sup> Though the output wavelength is similar to argon green, we hypothesized that some clinical or angiographic differences may exist.

ARVO 2000 Presentation  
Fiber Optic Fabrications, Inc., 515 Shaker Road, East Longmeadow, MA 01028

## Purpose

To study and compare the clinical, angiographic, and histologic effects of an FDYAG laser ( $\lambda=532$  nm) with an argon green laser ( $\lambda = 514$  nm) in a rabbit model.

Animals were used in accordance with the ARVO resolution on the use of animals in reasearch.

## Methods

Standardized laser burns of 0.1 second duration and 100  $\mu$  spot size were produced in 5 Dutch Belted rabbit eyes with both lasers varying application power between 50mW and 400mW to establish thresholds for the clinical endpoints of mild retinal blanching and breaking Bruch's membrane.

Comparable spots were placed with both lasers in a single eye to control for pigmentation variability.

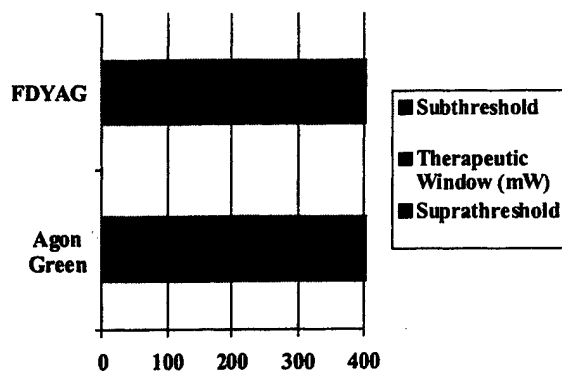
Treatment spots were compared acutely, and weekly out to four weeks with fundus photography, fluorescein angiography, and histology.

## Laser Sources

Ceralase solid state FDYAG laser manufactured by Ceramoptic, Inc. (East Longmeadow, MA) coupled through Haag Streitt laser couple and slit lamp (Bern, Switzerland).  
Coherent Argon laser model 920 (Santa Clara, CA).



## Threshold Results



Thresholds for barely visible retinal lesions:

FDYAG= 57.5mW, Argon green= 60mW.

Threshold for breaking Bruch's membrane:

FDYAG= 259 mW, Argon green=280mW.

## Clinical Endpoints



FDYAG ARGON

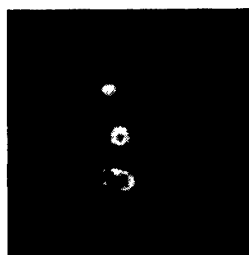


FDYAG ARGON

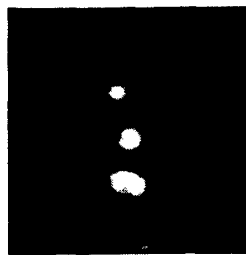
The FDYAG laser produced treatments clinically comparable to the argon green laser acutely with slightly lower thresholds for barely visible retinal lesions and for breaking Bruch's membrane

## Acute Angiography

a.

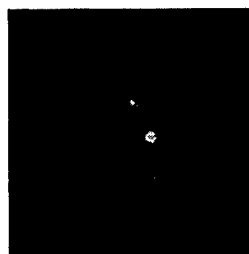


b.



FDYAG  
#40 OD  
early & late  
a=1:20,  
b=7:54

c.



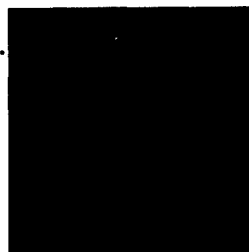
d.



ARGON  
#40 OD  
early & late  
c=0:09.7,  
d=0:39.2

## Angiography @ Two Weeks

a.

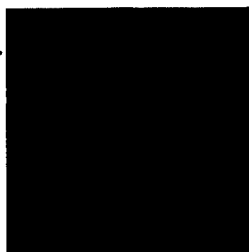


b.



FDYAG  
#40 OD  
2wks s/p laser  
a=1:47,  
b=5:19

c.



d.



ARGON  
#40 OD  
2wks s/p laser  
c=0:28  
d=5:29

## Histology

Histology of the FDYAG laser and argon green laser treatments showed coagulative necrosis of the outer retina, RPE, and choroid.

## Discussion

The threshold data for given clinical endpoints differed between the two lasers. The 532nm wavelength is more strongly absorbed by hemoglobin than 514nm. In the rabbit fundus (with relatively little RPE melanin) hemoglobin in the choriocapillaris may be a significant chromophore, lowering the thresholds.

Increased uptake by 532 nm output may be an aide in treating vascular lesions, but may reduce its efficacy when treating through hemorrhage.

## Conclusions

The cw FDYAG laser produces fundus lesions in the rabbit model which appeared clinically, angiographically and histologically indistinguishable from the argon green laser.

The cw FDYAG laser has slightly lower power requirements to produce comparable lesions in the rabbit fundus – resulting in a slightly smaller therapeutic window.

## References

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